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Summary

A total of 600 mixed parity sows (PIC, Line 3) were used to evaluate the effect of different lactation feeders and drip cooling on lactating sow farrowing performance and litter growth performance during summer conditions. For the lactation feeder evaluation, the trial was conducted in 2 sequential groups with 300 sows per group in the same facility in central Arkansas. Five rooms with 60 farrowing stalls per room were used for each group. At approximately d 110 to 112 of gestation, sows were blocked by body condition score (BCS), parity, and offspring genetics (Line 2 or Line 3 sires). Sows were then randomly allotted to 1 of 3 feeder designs: 1) PVC tube feeder; 2) Rotecna ball feeder (Rotecna, Agramunt, Spain); or 3) SowMax rod feeder (Hog Slat, Newton Grove, NC). The three feeder designs were placed in one of 3 farrowing stalls with the same sequence (Rotecna, SowMax, and then PVC tube feeder) from the front to the end of all farrowing rooms to balance the environmental effect in each room. For the drip cooling evaluation, the trial was conducted during the second group of 300 sows. Water drippers were blocked in 3 of every 6 farrowing stalls to balance the feeder types and the environmental effect in each room. Sows were weighed before entering the farrowing house and at weaning. Sows were provided approximately 4 lb per day of the lactation diet pre-farrowing. After farrowing, sows were provided *ad libitum* access to lactation feed. The weaning age was between 19 to 22 d. Viable piglets from sows bred to line 2 boars (7,562 piglets from 441 sows) were individually tagged with an RFID tag within 24 h after birth. Line 3 piglets were not tagged and not included in the litter performance data, but the sows of these piglets were included in the sow BW and feed disappearance data. After weaning, the cleaning times for each feeder type were recorded on a subsample of feeders (n = 67). For the effect of lactation feeders, there was no evidence of difference ($P > 0.05$) in sow entry BW, exit BW, BW change, and litter performance between sow lactation feeders. However, sows on SowMax feeders had lower ($P < 0.05$) total feed disappearance, average daily feed disappearance, and total feed cost than sows on the tube feeders. Therefore, the feed cost per pig weaned from sows on the SowMax feeder was improved ($P < 0.05$) compared to the tube feeders. There was a marginal difference ($P < 0.10$) between feeders in washing time, with tube feeders requiring less washing time than Rotecna ball feeders; however,

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washing time varied greatly between the individual people that power washed the room. Sows with drip cooling had greater ($P < 0.05$) sow feed disappearance and litter growth performance and reduced BW change, but also had a marginal difference of decreased ($P = 0.053$) percentage of sows bred back by d 30 after weaning, which needs further research to determine the cause.

Introduction

During the lactation period, maximizing sow feed intake is critical to reduce body reserve mobilization and sustain milk production for litter growth. Lactation feed intake also affects sow longevity and subsequent reproductive performance. However, sow farms located in warm and humid climates have difficulties maximizing lactation feed intake, which may lead to poorer performance. Several factors can affect sow feed intake, including feeder type and environmental comfort. There are several types of feeders in the market for use in farrowing stalls. A good farrowing stall feeder design can reduce feed wastage and improve sow feed intake by enhancing the accessibility of feed. However, the difficulty of cleaning the feeder also needs to be considered to avoid excess workload and cross-contamination of pathogens on the feeders to the next group of animals.

Drip cooling may reduce the discomfort of sows in a high-temperature environment and increase feed intake; however, the effect of drip cooling in a hot and humid environment is not clear. Therefore, the objective of this experiment was to evaluate the effect of lactation feeder designs and drip cooling on lactating sow farrowing performance, litter growth performance, and feeder cleaning criteria.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this study. The experiment was conducted at a commercial sow farm located in central Arkansas. There were 60 stalls per room. A total of 5 rooms (300 stalls; 100 stalls per lactation feeder treatment) were used for each group. The trial was conducted in 2 sequential groups for a total of 600 sows started on test.

Animals and sow lactation feeders

The first group of sows (PIC, Line 3) farrowed between June 6 and June 18, 2021, and the piglets were weaned between June 24 and July 7, 2021. The second group of sows farrowed between July 2 and July 15, and the piglets were weaned between July 25 and August 4, 2021. Sows were bred to line 2 (441 sows) and line 3 (159 sows) boars. At approximately d 110 to 112 of gestation, sows were moved to the farrowing house, and blocked by body condition score (BCS), parity, and offspring boar line. Sows were then randomly allotted to 1 of 3 feeder designs; 1) PVC tube feeder; 2) Rotecna ball feeder (Rotecna, Agramunt, Spain); or 3) SowMax rod feeder (Hog Slat, Newton Grove, NC, Figure 1). The three feeder designs were placed in one of 3 farrowing stalls with the same sequence (Rotecna, SowMax, and then PVC tube feeder) from the front to the end of all farrowing rooms to balance the environmental effect in each room (Figure 2). For the drip cooling evaluation, the trial was conducted during the second group of 300 sows. Water drippers were located above the stall and aimed at the shoulder region of the sow. The setpoint of the drip cooling system started at 76°F. The system ran on a 10-min cycle (2 min on and 8 min off). Water drippers were disabled in 3 of every 6 farrowing stalls and the sequence changed between rows to balance the feeder types and the environmental effect in each room (Figure 2). Evaporative cool cells started circulating at 78°F and were used in all farrowing rooms.

The same commercial sow lactation feed was fed to all sows. Sows were provided approximately 2 lb in the morning and 2 lb during late afternoon, for a total of 4 lb per day of the lactation diet pre-farrowing. After farrowing, sows were provided *ad libitum* access to the lactation feed. The hopper of each feeder was topped with lactation feed at least twice a day throughout the experiment. Each feed addition was weighed and recorded. Viable piglets from sows bred to Line 2 boars (7,562 piglets from 441 sows) were individually tagged with an RFID tag within 24 h of birth. Line 3 sired piglets were not tagged and not included in the litter performance data, but the sows of these piglets were included in the sow BW and feed disappearance data. If cross-fostering was needed, piglets were cross-fostered within 24 h of birth and within feeder type and offspring boar line. The weaning age was between 19 and 22 d.

Data and sample collection

The experiments' sow and litter data were recorded and stored using the LeeO system (Prairie Systems, Spencer, IA). For sow BW data, the number of sows used for control, Rotecna, and SowMax was 157, 153, and 151, with average parities of 2.8, 3.0, and 2.9, respectively. For feed disappearance, sow feed cost, and subsequent performance data, the number of sows used was 198, 194, and 191, with average parities of 3.0, 3.1, and 3.0. For litter performance data, the number of sows used was 145, 145, and 142, with average parities of 3.5, 3.6, and 3.5. For sow BW data, the number of sows used with dripper and without dripper was 121 and 124, with average parities of 2.9 and 2.9. For feed disappearance, sow feed cost, and subsequent performance data, the number of sows used were 145 and 149 for dripper and no dripper treatments, with average parities of 3.2 and 3.1, respectively. For litter performance data, the number of sows used was 111 and 108, with average parities of 3.7 and 3.5 for the dripper and no dripper treatments.

Each sow stall was tagged with an RFID tag and identified as a location pen in the LeeO system. For sow data, the information (sow ID, parity, breeding date, and offspring boar line) of each sow was exported from the PigChamp system and then imported into the LeeO system. A walk-on platform scale was used to weigh sows before entering the farrowing house and at weaning. When sows were placed in the farrowing stall, they were also registered in the location pens in the LeeO system. Feed carts equipped with scales were used to obtain the weight of each feed addition. Feed addition to each feeder was registered to the stall (location pen) with the date and weight recorded for calculating feed disappearance. Sow subsequent performance data were obtained from the PigChamp system. Sows that were culled due to old age were not included. For litter performance, tagged viable line 2 sired piglets were registered under the sow and location pen, and weighed individually at birth for farrowing performance and at weaning for litter performance. Non-viable piglets (low birth weight or dead before tagging), stillborn, and mummies were recorded but not weighed. Any cross-fostering and mortality throughout the lactation period were recorded. After weaning, 3 farm employees were designated to wash feeders, and cleaning times for several feeders per feeder type were recorded. The number of feeders used was 19, 23, and 25 for the PVC tube, Rotecna, and SowMax feeder, respectively. For economic data, the lactation feed cost was \$265/ton, litter value was \$0.70/lb of litter weight, and the labor cost for washing was \$15/h.

Statistical analysis

Data were analyzed as a randomized complete block design for one-way ANOVA in R program. The lmer function from the lme4 package was used for lactating sow BW, feed disappearance, litter growth performance, washing criteria, and economics. The glmer function (Poisson distribution) from the lme4 package was used for total born and litter size. The glmmTMB function (beta-binomial distribution) from the glmmTMB package was used for percent of live born, viable live born, non-viable live born, still-born, mummy, mortality, and pig weaned. The glmer function (binomial distribution) from the lme4 package was used for breed back data. Sow (litter) or feeder (washing criteria) were considered as the experimental unit. Groups and farrowing rooms were the blocking factors for sow and litter data. Washing personnel was used as the blocking factor for the washing criteria. Feeder type was used as the fixed effect. Sow entry weight was used as a covariate for weaning weight and weight change. Litter size was used as a covariate for feed disappearance, litter growth performance, and litter economic data. Total born was used as a covariate for litter birth weight. A Tukey/Sidak multiple comparison adjustment was used when appropriate. All results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Sow and litter performance

For the effect of sow lactation feeder, there was no evidence of difference ($P > 0.10$) in sow entry BW, weaning BW, BW change, and litter performance (Table 1). Sows fed with SowMax feeders had decreased ($P < 0.05$) total feed disappearance, average daily feed disappearance, and total feed cost compared to sows fed with tube feeders. Therefore, litter feed efficiency, feed cost per pig weaned, and feed cost per lb of litter weight gain for sows fed with the SowMax feeder were improved ($P < 0.05$) compared to the tube feeders. The results of feed disappearance and economics of sows fed with the Rotecna feeder were intermediate.

For the effect of drip cooling, sows provided with drip cooling had greater ($P < 0.05$) weaning BW, total feed disappearance, average daily feed disappearance, feed cost, and feed cost per pig weaned, and decreased ($P < 0.05$) BW change and percentage BW change (Table 2). There was no evidence of difference ($P > 0.10$) in litter criteria at farrowing, except sows without drip cooling had a greater ($P = 0.042$) percentage of viable live born than sows with drip cooling. At weaning, litter weaning weight, pig weaning weight, litter weight gain, and litter ADG of sows provided with drip cooling were greater ($P < 0.05$) than sows without drip cooling. There was no evidence of difference ($P > 0.10$) in litter feed efficiency, percentage of weaned pigs, or mortality. Drip cooling improved sow lactation performance; however, sows with drip cooling tended to have a decreased ($P = 0.053$) percentage of sows bred back by d 30 after weaning compared to sows without drip cooling.

Cleaning criteria

Rotecna ball feeders tended to have a greater ($P < 0.10$) washing time and washing cost compared to the PVC tube feeder (Table 1); however, the results were highly variable among the people who washed the feeders (Figure 3). The range of washing time per stall for the 3 people was from 30 to 71 s, 40 to 102 s, and 30 to 39 s, respectively.

In summary, the litter performance results suggest that sows fed with any of the lactation feeders had similar actual lactation feed intake; however, the different designs of lactation feeders affected the amount of feed wasted which was indicated by the difference in feed disappearance. This difference may be explained by the feed delivery method of each feeder. Because the only mechanism for the PVC tube feeder to control feed usage is the gap between the end of the PVC tube and the bottom of the feeder trough, the PVC tube feeder has an almost constant flow of feed to the feeder trough. SowMax and Rotecna require sows to voluntarily trigger the feed drop mechanisms of the feeder to deliver feed to the trough. Though the feed coverage of the trough was not recorded, the troughs of the PVC tube feeder had a greater frequency of excessive feed coverage than other feeders through daily observation, even with daily feeder adjustment. Therefore, PVC tube feeder resulted in greater feed disappearance (wastage) than other feeders. For sows with drip cooling, even though they had greater feed cost and feed cost per pig weaned, these sows had reduced BW loss and improved lactation performance, indicated by the greater weaned pig weight and litter value, with no difference in litter feed efficiency. However, these sows had a lower percentage bred back by d 30 after weaning, which needs further investigation to determine what caused this reduction.

Table 1. The effect of sow lactation feeder on sow and litter performance[1]

	PVC tube	Rotecna	SowMax	SEM	*P*-value
Sow body weight, lb					
Entry	492.1	488.1	496.3	10.13	0.580
Weaning[3]	427.8	429.6	426.9	6.07	0.725
Weight change[3]	-69.2	-67.4	-70.1	6.07	0.725
Weight change, %[3]	14.1	13.7	14.2	1.22	0.724
Total feed disappearance, lb					
All sows	296.9[a]	287.5[ab]	281.2[b]	14.32	0.056
Sows with litter data[4]	313.6[a]	307.5[a]	290.7[b]	17.77	0.003
Average daily feed disappearance, lb					
All sows	13.8[a]	13.4[ab]	13.1[b]	0.694	0.027
Sows with litter data[4]	14.6[a]	14.3[a]	13.5[b]	0.813	0.002
Litter performance[3]					
Lactation length, d	21.5	21.5	21.5	0.43	0.994
Total born, n	17.5	17.2	16.8	0.35	0.356
Live born, % of total born	91.3	92.7	91.9	0.76	0.402
Viable live born, % total born	82.6[y]	85.8[x]	83.9[xy]	1.11	0.099
Nonviable live born, % of total born	8.5	7.3	8.0	0.78	0.478
Stillborn, % of total born	7.6	6.0	7.3	0.71	0.196
Mummified, % of total born	1.1	1.1	0.9	0.26	0.658
Litter birth weight, lb[5]	44.3	44.4	43.4	0.82	0.600
Pig birth weight, lb[5]	3.2	3.1	3.1	0.04	0.156
Litter size at 24 h, n	14.5	14.8	14.0	0.32	0.226
Litter weaning weight, lb[4]	161.6	164.4	164.0	5.36	0.588
Pig weaning weight, lb[4]	12.5	12.8	12.7	0.35	0.328
Litter weight gain, lb[4]	117.2	120.8	120.1	5.63	0.406
Litter average daily gain, lb[4]	5.45	5.60	5.57	0.244	0.452
Litter feed efficiency[4,6]	2.79[a]	2.65[ab]	2.53[b]	0.074	0.021
Weaned, % of litter size	89.5	89.0	90.7	0.83	0.702
Pre-weaned mortality, % of live born[7]	18.7	17.9	16.8	1.09	0.440
Pre-weaned mortality, % of litter size[8]	10.5	11.0	9.3	0.83	0.285
Sow subsequent performance[9]					
Bred back within 30 d, %	92.0	90.8	88.1	2.95	0.410
Bred back within 14 d, %	77.4	75.3	71.8	3.55	0.453

continued

Table 1. The effect of sow lactation feeder on sow and litter performance[1]

	PVC tube	Rotecna	SowMax	SEM	*P*-value
Economics, $[10]					
Litter value[4]	113.15	115.05	114.78	3.752	0.588
Total lactation feed cost					
All sows	39.34[a]	38.09[ab]	37.26[b]	1.899	0.055
Sows with litter data[4]	41.55[a]	40.74[a]	38.52[b]	2.354	0.003
Litter value over lactation feed cost[4]	71.39[y]	74.34[xy]	76.06[x]	1.777	0.060
Feed cost per pig weaned[4]	3.26[a]	3.22[ab]	3.02[b]	0.172	0.014
Feed cost per lb of litter weight gain[4]	0.37[a]	0.35[ab]	0.34[b]	0.010	0.021
Washing time per feeder, s	43.6[y]	53.3[x]	51.0[xy]	10.01	0.053
Washing cost per feeder	0.18[y]	0.22[x]	0.21[xy]	0.042	0.053

[1] A total of 600 mixed parity sows (PIC, Line 3) that were bred to Line 2 and Line 3 boars were used with 200 sows per treatment. Piglets of sows bred to Line 2 boars were included in the litter performance data. Sows were weighed on d 110, 111, or 112 of gestation, blocked by parity category and BCS, and allotted to treatment stalls at the time of entry to the farrowing house. For sow body weight data, the number of sows used for control, Rotecna, and SowMax were 157, 153, and 151, with average parities of 2.8, 3.0, and 2.9, respectively. For feed disappearance, sow feed cost, and subsequent performance data, the number of sows used for the three feeders was 198, 194, and 191, with average parities of 3.0, 3.1, and 3.0, respectively. For litter performance data, the number of sows used was 145, 145, and 142, with average parities of 3.5, 3.6, and 3.5, respectively. For the feeder washing data, the number of feeders used was 19, 23, and 25 for the three feeders, respectively.

[3]Entry BW was used as a covariate.

[4]Litter size was used as a covariate.

[5]Total born was used as a covariate.

[6]Litter feed efficiency = total feed disappearance ÷ total litter weight gain.

[7]Pre-weaned mortality, % of live born = [(total dead after birth) ÷ (viable live-born + non-viable live-born)] × 100%.

[8]Pre-weaned mortality, % of litter size = [(dead after cross-fostering) ÷ (litter size at 24 h)] × 100%.

[9]Subsequent performance data were obtained approximately one month after weaning. Sows that were culled due to old age were not included.

[10]Lactation feed cost was $265/ton, and the labor cost for washing was $15/h. Litter value = litter weaning weight × $0.70 per lb.

[a,b] Means within a row with different superscripts differ ($P \leq 0.05$).

[x,y] Means within a row with different superscripts differ ($0.05 < P \leq 0.10$).

Table 2. The effect of drip cooling on sow and litter performance[1]

	Without dripper	With dripper	SEM	*P*-value
Sow body weight, lb				
Entry	479.1	482.2	17.6	0.731
Weaning[3]	416.5	424.3	6.9	0.028
Weight change[3]	-75.1	-67.2	6.9	0.028
Weight change, %[3]	15.5	13.9	1.41	0.023
Total feed disappearance, lb				
All sows	267.5	298.1	19.0	< 0.001
Sows with litter data[4]	280.0	318.3	22.0	< 0.001
Average daily feed disappearance, lb				
All sows	12.2	13.6	0.89	< 0.001
Sows with litter data[4]	12.8	14.5	0.91	< 0.001
Litter performance				
Lactation length, d	21.9	21.9	0.57	0.926
Total born, n	17.6	17.6	0.40	0.989
Live born, % of total born	92.2	90.6	0.88	0.173
Viable live born, % total born	85.4	81.9	1.27	0.042
Nonviable live born, % of total born	7.1	8.5	0.87	0.229
Stillborn, % of total born	6.3	8.0	0.81	0.117
Mummified, % of total born	1.5	1.4	0.32	0.822
Litter birth weight, lb[5]	45.5	44.0	0.88	0.201
Pig birth weight, lb[5]	3.1	3.1	0.04	0.371
Litter size at 24 h, n	14.8	14.5	0.37	0.610
Litter weaning weight, lb[4]	158.1	165.4	7.16	0.034
Pig weaning weight, lb[4]	12.2	12.7	0.48	0.025
Litter weight gain, lb[4]	112.8	121.3	7.2	0.015
Litter average daily gain, lb[4]	5.1	5.5	0.24	0.012
Litter feed efficiency[4,6]	2.63	2.77	0.101	0.234
Weaned, % of litter size	88.6	89.8	0.95	0.332
Pre-weaned mortality, % of live born[7]	18.2	18.4	1.20	0.890
Pre-weaned mortality, % of litter size[8]	11.4	10.2	0.95	0.332
Sow subsequent performance[9]				
Bred back within 30 d, %	95.7	90.3	4.13	0.053
Bred back within 14 d, %	73.1	74.3	4.30	0.818

continued

Table 2. The effect of drip cooling on sow and litter performance[1]

	Without dripper	With dripper	SEM	*P*-value
Economics, $[10]				
Sow weaning weight value[3]	249.87	254.60	4.16	0.028
Litter value[4]	110.67	115.77	5.01	0.034
Total lactation feed cost				
All sows	35.46	39.50	2.52	< 0.001
Sows with litter data[4]	37.10	42.17	2.91	< 0.001
Litter value over lactation feed cost[4]	73.42	73.59	2.646	0.944
Feed cost per pig weaned[4]	2.90	3.27	0.223	< 0.001
Feed cost per lb of litter weight gain[4]	0.35	0.37	0.013	0.234

[1] A total of 300 mixed parity sows (PIC, Line 3) that were bred to Line 2 and Line 3 boars were used with 150 sows per treatment. Piglets of sows bred to Line 2 boars were included in the litter performance data. Sows were weighed on d 110, 111, or 112 of gestation, blocked by parity category and BCS, and allotted to treatment stalls at the time of entry to the farrowing house. For sow body weight data, the number of sows used with dripper or without dripper was 121 and 124, with average parities of 2.9 and 2.9, respectively. For feed disappearance, sow feed cost, and subsequent performance data, the number of sows used for the two treatments was 145 and 149, with average parities of 3.2 and 3.1, respectively. For litter performance data, the number of sows used was 111 and 108, with average parities of 3.7 and 3.5, respectively.

[3]Entry BW was used as a covariate.

[4]Litter size was used as a covariate.

[5]Total born was used as a covariate.

[6]Litter feed efficiency = total feed disappearance ÷ total litter weight gain.

[7]Pre-weaned mortality, % of live born = [(total dead after birth) ÷ (viable live-born + non-viable live-born)] × 100%.

[8]Pre-weaned mortality, % of litter size = [(dead after cross-fostering) ÷ (litter size at 24 h)] × 100%

[9]Subsequent performance data were obtained approximately one month after weaning. Sows that were culled due to old age were not included.

[10]Lactation feed cost was $265/ton. Sow weaning weight value = sow weaning weight × $0.60 per lb. Litter value = litter weaning weight × $0.70 per lb.

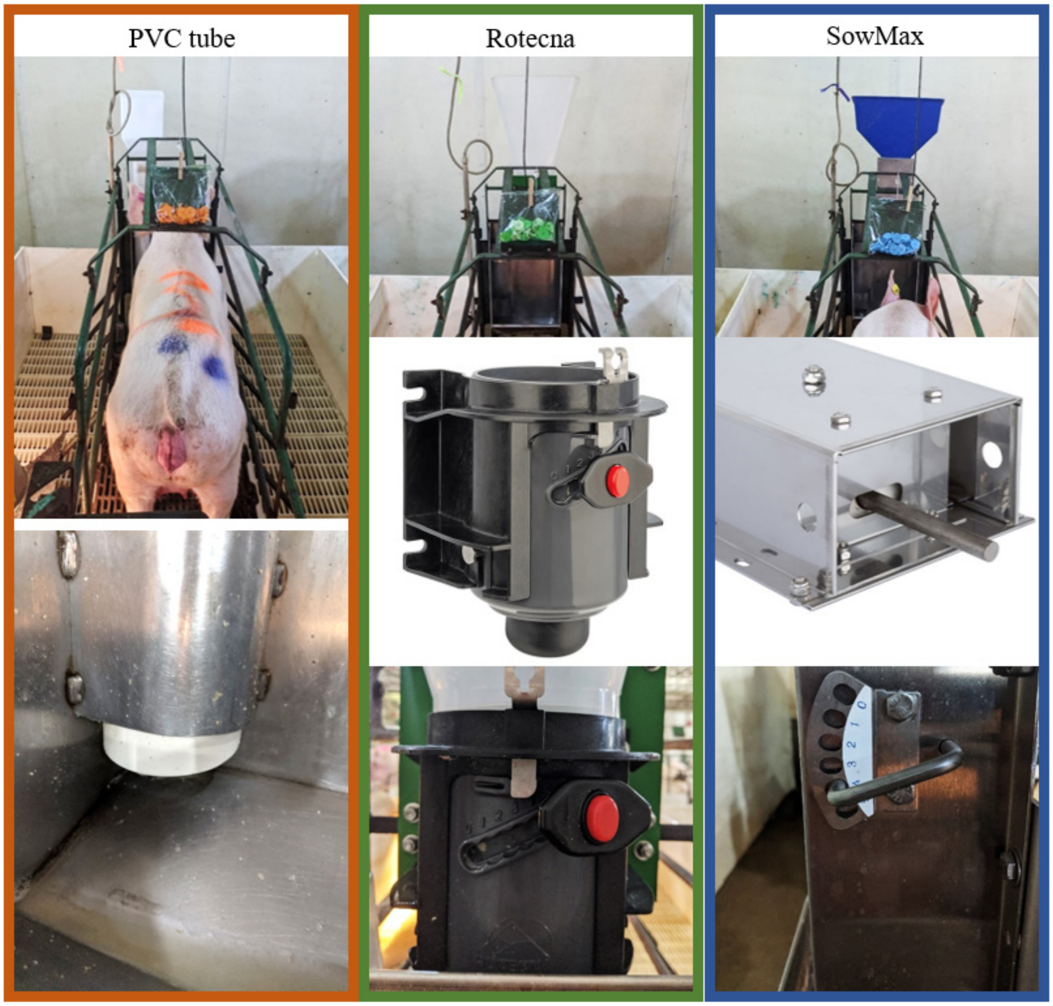

Figure 1. Sow lactation feeders, feeder trigger, and adjustment mechanisms. For feeder adjustment, the PVC tubes were pushed against the feeder wall by a screw to maintain the gap between the end of the PVC tube and the bottom of the trough with friction. The Rotecna and SowMax feeders had quick adjustment handles to control the amount of feed dropped (gap size) for each trigger by the sows. For the trigger mechanism, Rotecna has a ball structure that can be pushed up from all directions and opens a gap to allow feed to drop. SowMax has a rod that can be pushed sideways and opens a gap on the sides of the hopper to allow feed to drop.

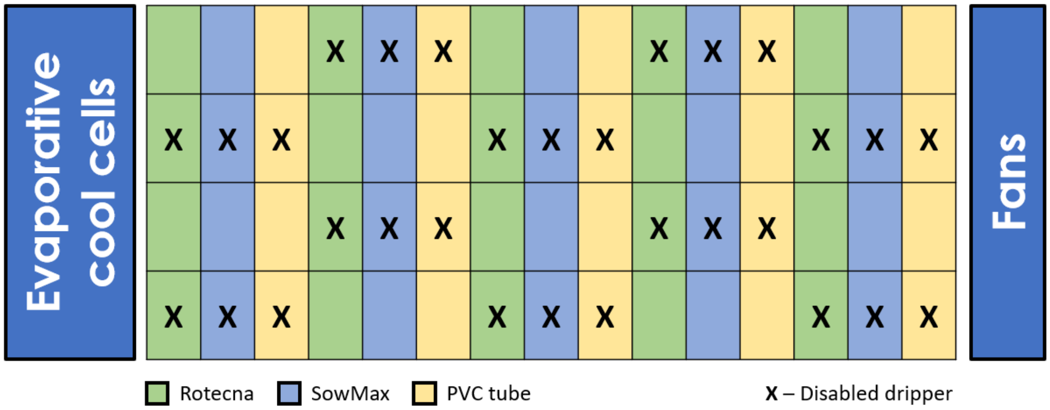

Figure 2. Example of lactation feeder and drip cooling setup in a farrowing room. Five rooms with 60 stalls per room were used. Every cell represents a farrowing stall. Rotecna, SowMax, and PVC tube feeders were installed in green, blue, and yellow cells, respectively. Water drippers were disabled in cells that contain an "X".

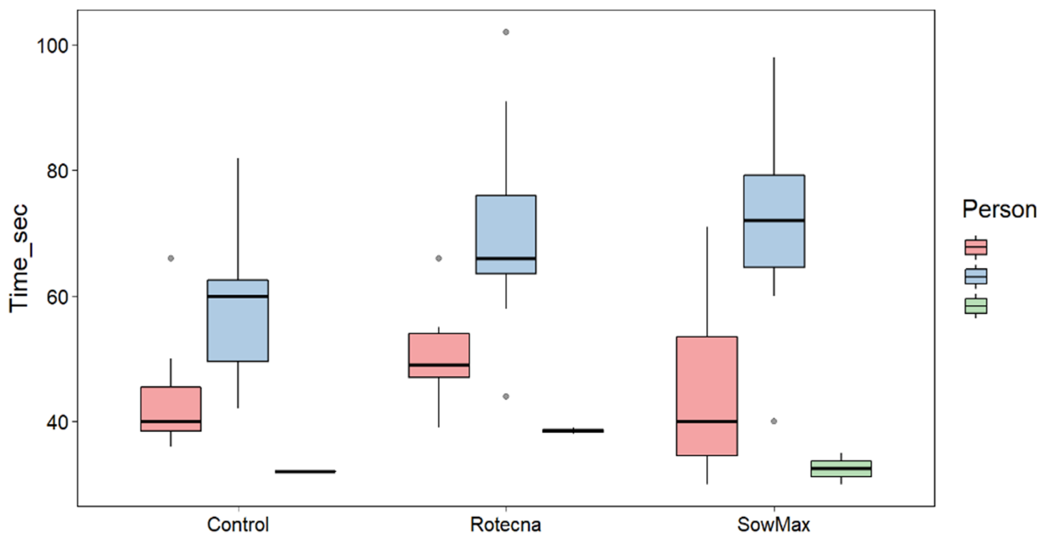

Figure 3. Feeder washing time per feeder by personnel. After weaning, the feeders were washed by 3 farm employees and the cleaning times for several feeders per feeder type were recorded. The number of feeders used was 19, 23, and 25 for the PVC tube, Rotecna, and SowMax feeder, respectively. Each color represents a distinct farm employee. The results varied highly between the people who washed the feeders. The range of washing time for the 3 people was from 30 to 71 s (red), 40 to 102 s (blue), and 30 to 39 s (green), respectively.